PROGRAMMED INSTRUCTION

MAGNETIC THEORY

X-1

Naval Air Technical Training Comma

CNTT-M154 Rev. 3-77

netic Theory

dent will:

t two reasons why the earth may be compared to a bar magnet.

te to which of the magnetic poles of the earth (N or S) the north larized end of a compass needle points; explain your answer.

el, on the drawing provided, the north and south magnetic and graphic poles of the earth.

licate with arrows, on the drawing provided, the direction of the ernal and external magnetic lines of force of the earth.

te the approximate angle, in relation to the surface, of the th's external lines of force at the poles and at the equator.

te the term which indicates the relationship of the angle between earth's magnetic lines of force and the earth's surface.

te the commonest unit of measurement used to measure the intensity strength of the earth's magnetic field.

te the intensity of the earth's magnetic field at the equator and the magnetic poles.

t two reasons why the earth's magnetic field is not symmetrical.

t the three magnetic moments of a submarine.

t the two types of magnetism which comprise each of the three netic moments of a submarine.

te the term that describes the distortion of the earth's magnetic ld which is caused by a submarine's dipole moment.

SUGGESTED READING TIME 50 MINUTES

The following is a brief review of [illegible]

It consists of two parts: (1) A number of statements and (2) a matching test concerning these statements.

NOTE: For a more comprehensive review of magnetic theory, review the programmed instruction booklet MAGNETIC THEORY-Magnetism P-IV-1.

1. MAGNETISM is the study of the properties of magnets and magnetic materials.

2. MAGNETS are substances which have the ability to attract other magnetic materials.

3. RETENTIVITY is the ability of a material to retain its magnetism after the removal of the magnetizing force.

4. PERMEABILITY is a measure of how much better a material is, than air, as a path for magnetic lines of force.

5. RELUCTANCE is the opposition (resistance) offered by a magnetic substance to the passage of the magnetic flux.

6. PERMEANCE is the property of a substance that permits lines of flux to pass through (the opposite of reluctance).

7. RESIDUAL MAGNETISM is the magnetism which remains in a magnetic material after the magnetizing force is removed.

8. MAGNETIC INDUCTION is inducing magnetism in an object by external means.

9. A MAGNETIC DOMAIN is a microscopic region made up of atoms that are magnetically aligned in one direction.

10. The two SOURCES of magnetism are NATURAL and ARTIFICIAL magnets.

11. The two TYPES of artificial magnets are PERMANENT and TEMPORARY.

12. The first two laws of magnetism are: LIKE POLES REPEL EACH OTHER; UNLIKE POLES ATTRACT EACH OTHER.

13. PERMANENT MAGNETS are made of hardened steel and various alloys which are difficult to magnetize but retain most of their magnetism after the magnetizing force has been removed (high retentivity).

14. TEMPORARY MAGNETS are made of soft iron or other materials which are easy to magnetize but lose most of their magnetism when the magnetizing force is removed (low retentivity).

1. Magnetism	____	A. The property of a substance that permi lines of flux to pass through.
2. Magnets	____	B. The ability of a material to retain it magnetism after the removal of the magnetizing force.
3. Retentivity	____	C. A microscopic region made up of atoms that are magnetically aligned in one direction.
4. Permeability	____	D. Made of soft iron or other materials which are easy to magnetize but have low retentivity.
5. Reluctance	____	E. The study of the properties of magnets and magnetic materials.
6. Permeance	____	F. The two types of artificial magnets.
7. Residual magnetism	____	G. Made of hardened steel or alloys which are difficult to magnetize but which have a high retentivity.
8. Magnetic induction	____	H. Inducing magnetism in an object by external means.
9. Magnetic domain	____	I. The opposition offered by a magnetic substance to the passage of the magnet lines of force.
10. Natural and artificial	____	J. The two sources of magnetism.
11. Permanent and temporary magnets	____	K. The magnetism which remains in a magne material after the magnetising force i removed.
12. The first two laws of magnetism	____	L. The measure of how much better a mater is, than air, as a path for magnetic lines of force.
13. Permanent magnets	____	M. Like poles repel each other; unlike poles attract each other.
14. Temporary magnets	____	N. Substances which have the ability to attract other magnetic materials.

surrounding the magnet are lines of flux which flow externally from north to south and internally from south to north, forming a closed loop.

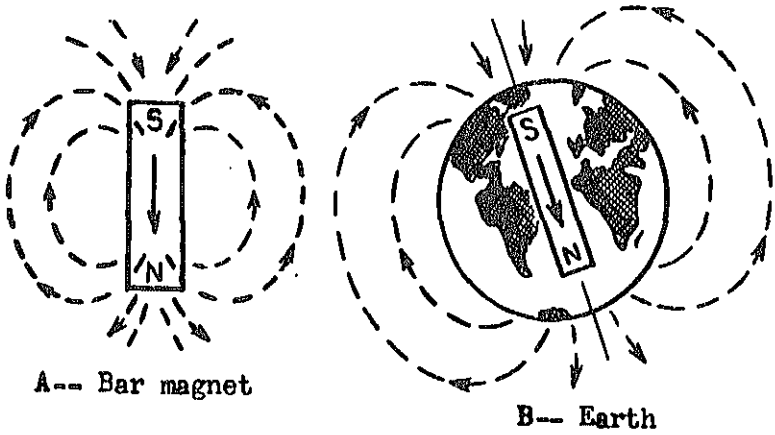
The strength of this magnetic field can be measured. The area of greatest strength lies at the poles and the area of least strength lies midway between the poles.

The earth can be compared to a bar magnet, since it exhibits all the properties of a bar magnet.

Primarily, it has

(1) a north and a south magnetic pole, and

(2) magnetic lines of force which can be measured.



A-- Bar magnet

B-- Earth

Figure 1

Two reasons why the earth can be compared to a bar magnet are:

(1) It has a north and a south magnetic pole, and

(2) _____

_____.

measured.

_____.

bar magnet

3. See figure 3. A compass needle is a small bar magnet with the north polarized end marked with an N. This end of the compass needle always points toward the geographic north pole. However, applying the first two rules of magnetism (LIKE POLES REPEL EACH OTHER; UNLIKE POLES ATTRACT EACH OTHER) it should be apparent, that in pointing toward the north geographic pole, the NORTH POLARIZED end of the compass needle is, in reality, pointing at the SOUTH MAGNETIC pole. (The compass needle actually aligns with the earth's magnetic lines of force.)

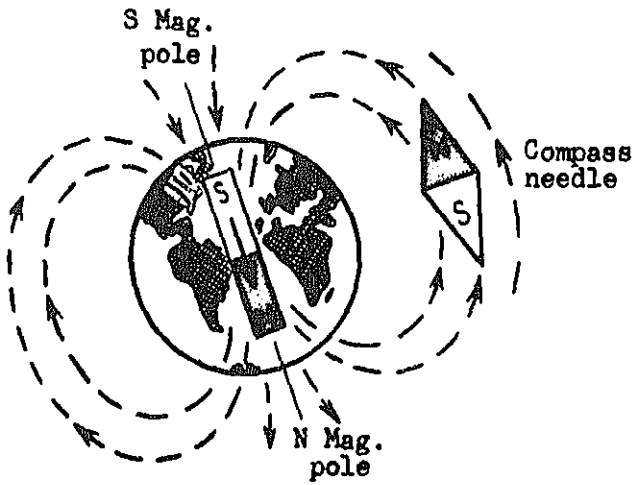


Figure 3-- North end of compass needle points at south magnetic pole.

The north polarized end of a compass needle points toward the _____ magnetic pole of the eart
(north/south)

because _____.

es repel;
oles

4. The north polarized end of a compass needle points toward the _____ magnetic (north/south) pole of the earth because

   a. like poles repel; like poles attract.

   b. unlike poles attract; unlike poles repel.

   c. like poles repel; unlike poles attract.

   d. unlike poles repel; like poles attract.

5. List two reasons why the earth can be compared to a bar magnet.

   (1) _____

   _____

   _____

   (2) _____

   _____

   _____

and south magnetic poles.

(2) It has magnetic lines of force which can be measured.

fore the magnetic and geographic poles are not located at the same place on the surface of the earth. Because of this fact, a compass will not (except at certain positions on the earth) point on a line which will be through both the geographi and magnetic poles, but will point at some angle to the geographic pole. (This angle is called the angle of variation or declination.)

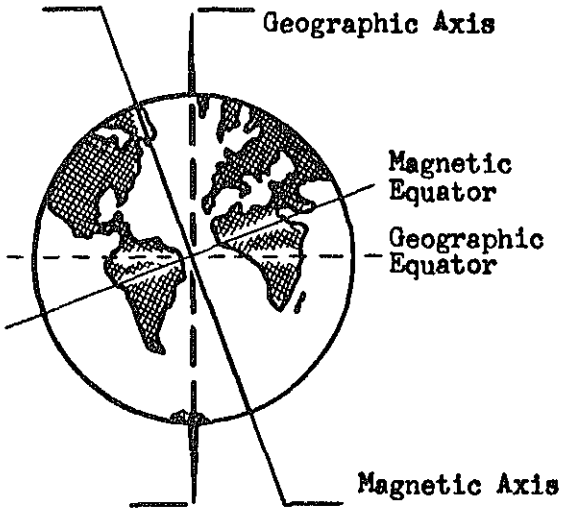
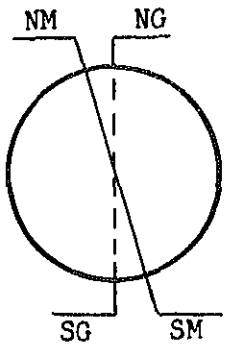


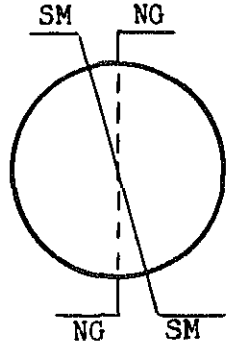
Figure 6-- Magnetic and geographic axis of the earth.

On figure 6, label with NG, SG, NM,and SM the magnetic and geographic poles of the earth.

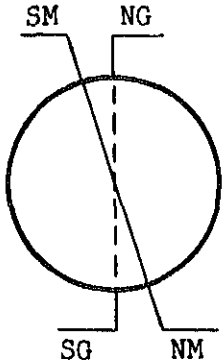
7. Select the drawing below which shows the correct labeling of the magnetic and geographic poles.



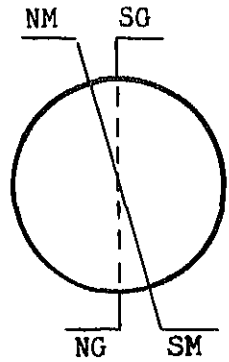
A



B



C



D

8. To which of the magnetic poles of the earth (N or S) does the north polarized end of a compass needle point? Explain.

a. _____

b. _____

repel; unlike poles attract.

(1) _____

_____

(2) _____

_____

(1) It has a north and a south magnetic pole.

(2) It has magnetic lines of force which can be measured.

10. See figure 10. In a bar magnet, the external lines of force flow from the north magnetic pole to the south magnetic pole and internally from the south to the north pole, forming a closed loop. The same rule applies to the magnetic lines of force of the earth.

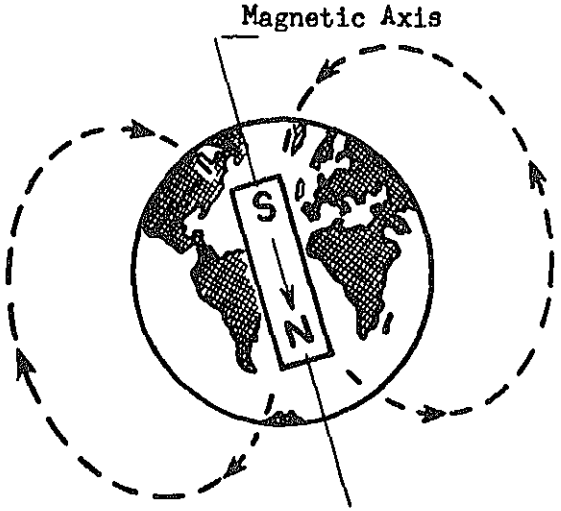
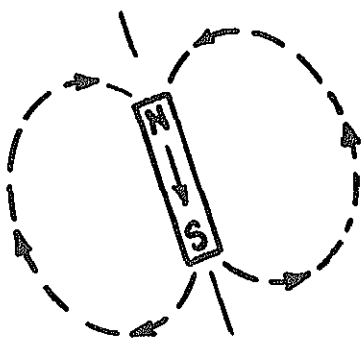


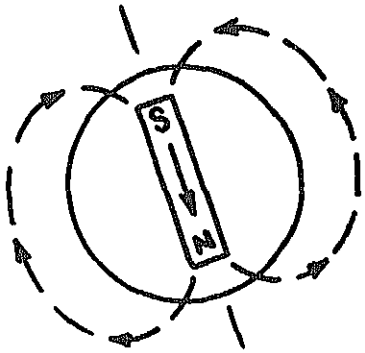
Figure 10-- Earth's magnetic lines of force.

Internal lines of force flow from the _____ pole to the _____ pole and external lines of force flow from the _____ pole to the _____ pole.

show the correct direction of the flow of the magnetic lines of force.



A



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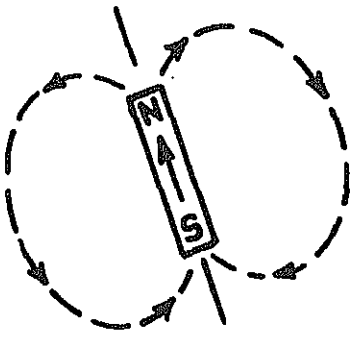
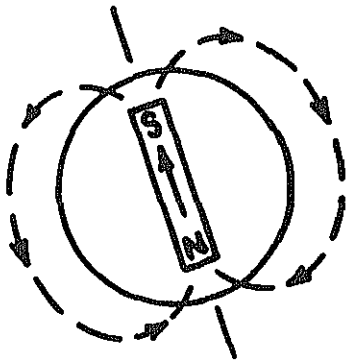


C



D

12. The south magnetic pole is located in the vicinity of the _____ geographic pole and the north magnetic pole is located in the vicinity of the _____ geographic pole.

north

south

13. To which of the magnetic poles of the earth (N or S) does the north polarized end of a compass needle point? Explain.

a. _____

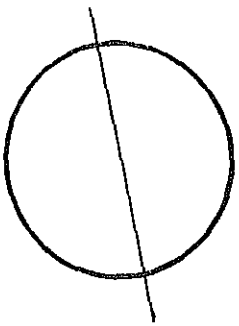
b. _____

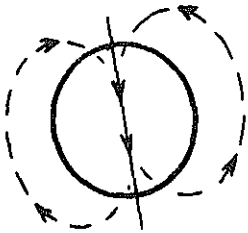
_____

a. South.

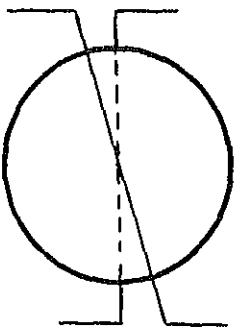
b. Like poles repel; unlike poles attract.

14. On the drawing below, draw the magnetic lines of force and indicate with arrows the direction of the lines of force.





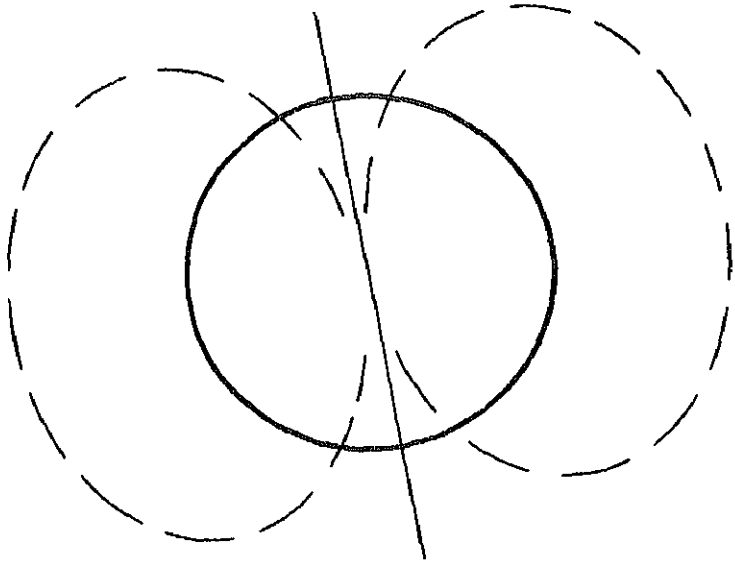
15. Label, on the drawing below, the magnetic and geographic poles of the earth.

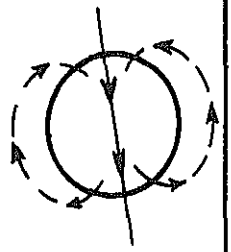


NG

NM

the direction of the internal and external magnetic lines of force of the earth.





17. See figure 17. At the equator, the angle of the earth's external magnetic lines of force, in relation to the surface, is approximately 0°. At the poles, the angle has increased to approximately 90° to the earth's surface.

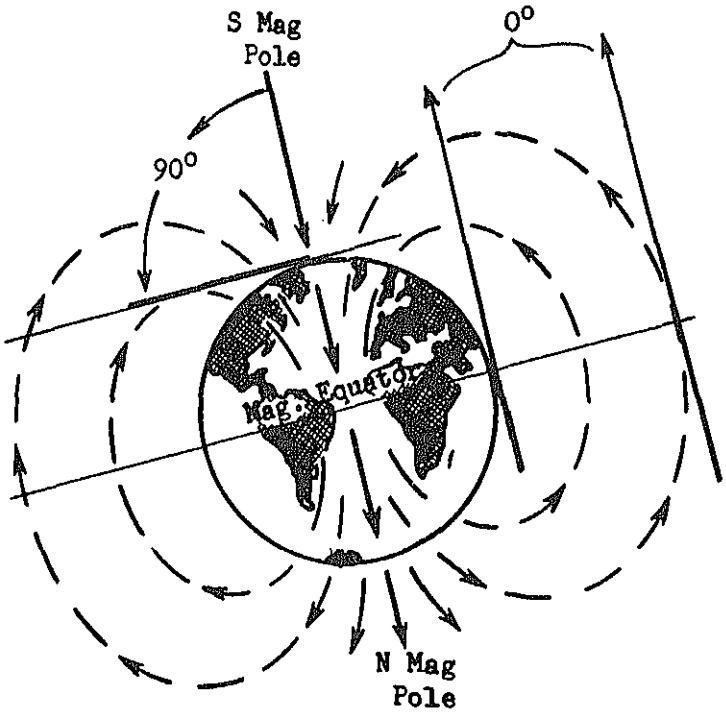


Figure 17

In relation to the earth's surface, the angle of the external lines of force at the poles is _____ degrees and at the equator the angle is _____ degrees.

90°
0°

18. In relation to the surface, the angles of the external lines of force of the earth are

a. 90° at the magnetic poles and 90° at the equator.

b. 0° at the poles and 90° at the equator.

c. 0° at the poles and 0° at the equator.

d. 0° at the equator and 90° at the poles.

of the angle between the earth's surface and the magnetic lines of force is between 0° and 90°. This angle is determined by drawing an imaginary line tangent to the earth's surface and to the line of force where it enters the earth's surface. The angle thus formed is called the DIP ANGLE. (The angle at which the lines of force "dip" toward the surface of the earth at any given point.)

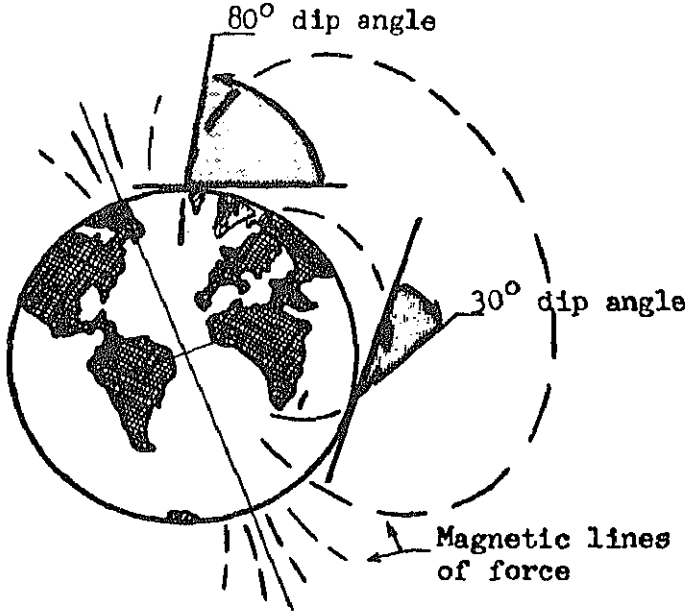


Figure 19-- Dip Angles.

The relationship of the angle between the earth's magnetic lines of force and the earth's surface is called the _____.

dip angle	20. DIP ANGLE is the angle at which the lines of force dip toward or enter the _____ of the earth.
surface	21. At the poles, the approximate angle at which the external lines of force enter the surface of the earth is _____, and at the equator, the angle is _____ to the surface.
90° 0°	22. The relationship of the angle between the earth's magnetic lines of force and the earth's surface is the _____.
dip angle	23. What are the approximate angles, in relation to the surface, of the earth's external lines of force at the poles and at the equator? a. Poles: _____ b. Equator: _____
90° 0°	24. What is the term which indicates the relationship of the angle between the earth's magnetic lines of force and the surface of the earth? _____

angle.

netic line of force per square meter. Since the operation of magnetic anomaly detection (MAD) equipment requires the detection of extremely small changes in magnetic intensity, the oersted is too large a unit of measurement to be practical.

The unit of measurement used to measure the intensity of the earth's magnetic field with MAD equipment is the GAMMA.

The GAMMA is 10^{-5} oersteds; or 100,000 GAMMAS equal one oersted; or one magnetic line of force per 100,000 square meters of unit area equals one GAMMA of magnetic intensity.

The unit of measurement used to measure the intensity of the earth's magnetic field with MAD equipment is the _____.

ma

26. The unit of measurement used with MAD equipment to measure the intensity of the magnetic field of the earth is the

    a. oersted.

    b. gauss.

    c. gilbert.

    d. gamma.

d.

27. In a bar magnet, as stated previously, the area of greatest magnetic intensity lies at the poles and the area of least magnetic intensity lies midway between the poles. This same relationship holds true for the earth's magnetic field. The area of the greatest magnetic intensity is at the magnetic poles and the least magnetic intensity is at the magnetic equator.

The intensity of the earth's magnetic field varies from about 65,000 gammas at the magnetic poles to about 25,000 gammas at the magnetic equator.

The intensity of the earth's magnetic field at the equator is about _____ gammas and at the magnetic poles about _____ gammas.

25,000
65,000

28. The intensity of the magnetic field of the earth is

a. 65,000 gammas at the equator and 25,000 gammas at the poles.

b. 65,000 gammas at the poles and 25,000 gammas at the equator.

c. 25,000 gammas at the poles and 25,000 gammas at the equator.

d. 65,000 gammas at the poles and 65,000 gammas at the equator.

b.

29. The gamma is a unit of measurement of the intensity of the _____ _____ of the earth.

iron rather than through the atmosphere. Consequently, the magnetic field of the bar magnet becomes distorted and is no longer symmetrical.

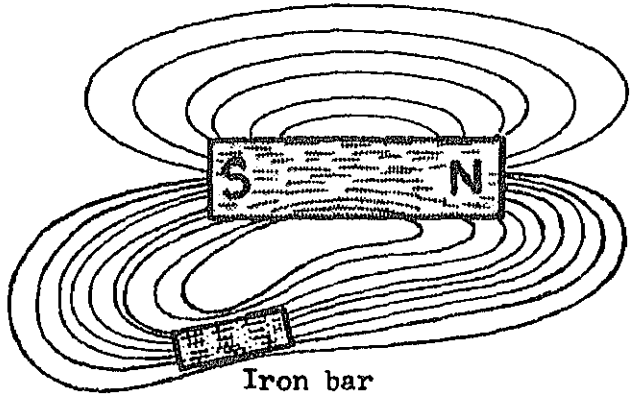


Figure 30

Since, within the surface of the earth, there are deposits of petroleum, iron ore, and other minerals, a similar distortion of the earth's magnetic field occurs.

Ore deposits tend to attract lines of force and an area of greater field strength results.

Petroleum deposits tend to repel lines of force and a weaker field strength occurs in this area.

Two reasons why the earth's magnetic field is not symmetrical, are as follows:

(1) Ore deposits tend to _____ lines of force.

(2) Petroleum deposits tend to _____ lines of force.

attract repel	31. The magnetic field of the earth is not symmetrical because a. ore deposits tend to attract lines of force and petroleum deposits tend to attract lines of force. b. ore deposits tend to attract lines of force and petroleum deposits tend to repel lines of force. c. ore deposits tend to repel lines of force and petroleum deposits tend to attract lines of force. d. ore deposits tend to repel lines of force and petroleum deposits tend to repel lines of force.
b.	32. The intensity of the magnetic field of the earth is _____ gammas at the magnetic poles and _____ gammas at the magnetic equator.
65,000 25,000	33. What is a unit of measurement used to measure the strength of the earth's magnetic field? _____

Gamma.

34. The earth's magnetic field is not symmetrical because:

(1) _____

_____

(2) _____

_____

(1) Ore deposits attract lines of force.
(2) Petroleum deposits repel lines of force.

35. What is the intensity of the earth's magnetic field at the equator and at the magnetic poles?

a. Equator: _____

b. Magnetic poles: _____

25,000 gammas

65,000 gammas

36. List two reasons why the earth's magnetic field is not symmetrical.

(1) _____

_____

_____

(2) _____

_____

_____

ttract lines
f force.

) Petroleum
eposits repel
ines of force.

netic field with properties similar to a permanent magnet. The magnetic field is actually composed of three separate magnetic forces. The three magnetic forces interact with one another to form the total magnetic field, which is referred to as the submarine's DIPOLE MOMENT.

A submarine has three magnetic forces (referred to as "magnetic moments"):

(1) Longitudinal moment--the magnetic force along the length of the submarine (fore and aft).

(2) Vertical moment--the magnetic force through the height of the submarine.

(3) Transverse moment--the magnetic force through the width of the submarine (horizontal).

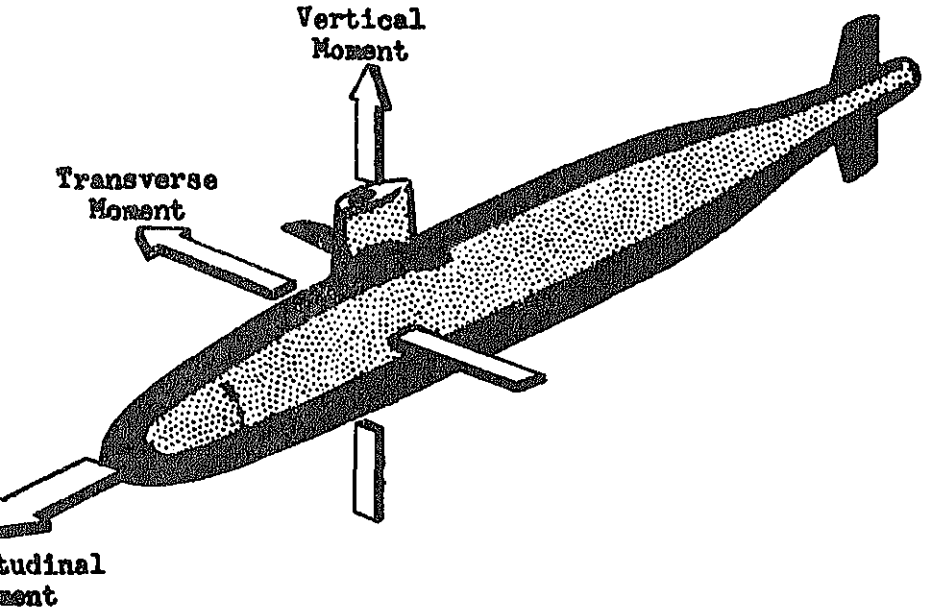
NOTE: See the drawing on page 21--The Three Magnetic Moments of a Submarine.

The three separate magnetic fields which make up the submarine's total magnetic field or dipole moment are:

(1) _____ moment (through the length of the submarine).

(2) _____ moment (through the height of the submarine).

(3) _____ moment (through the width of the submarine).



THE THREE MAGNETIC MOMENTS OF A SUBMARINE

Vertical

Transverse

separate magnetic moments:

(1) The longitudinal moment, which is through the _____ of the submarine.

(2) The vertical moment, which is through the _____ of the submarine.

(3) The transverse moment, which is through the _____ of the submarine.

length

height

width

39. Each of the three magnetic moments of a submarine is made up of two types of magnetism:

(1) permanent magnetism and

(2) induced magnetism.

Since a submarine is constructed of metal, it has some permanent magnetism. Also, a submarine traveling from one point to another cuts the earth's magnetic lines of force. This induces magnetism into the submarine.

The amount of induced magnetism depends upon the heading of the submarine and the region of dip angle in which it is operating.

For example, the intensity of the induced magnetism in the vertical moment depends entirely on the region of dip angle, whereas the intensity of the induced magnetism in the longitudinal moment is primarily a result of the heading of the submarine.

Each of the three magnetic moments of a submarine is made up of both _____ magnetism and _____ magnetism. This vectorial sum is the targets total magnetic field or dipole moment.

40. The three magnetic moments of a submarine are
    a. longitudinal, vertical, and height.
    b. longitudinal, vertical, and lengthwise.
    c. longitudinal, transverse, and crosswise.
    d. longitudinal, transverse, and vertical.

41. Three separate magnetic moments make up the total magnetic field or dipole moment of a submarine.

    (1) _____ -- through the fore-and-aft length of the submarine.

    (2) _____ -- through the height of the submarine.

    (3) _____ -- through the horizontal width of the submarine.

(1) Longitudinal
(2) Vertical
(3) Transverse

42. A bar of iron, placed in the field of a b magnet, distorts the normally symmetrical magnetic field of the magnet. Likewise, ore deposit in the crust of the earth dis the magnetic field of the earth. Therefo logical assumption is that a submarine, h magnetic properties similar to a bar magn also distorts the magnetic field of the e

The distortion of the earth's magnetic fi whether by an ore deposit, a ship, or a submarine , is referred to as a MAGNETIC ANOMALY.

The word ANOMALY is defined as "a departu from the regular arrangement", or as an "abnormality." When considering the eart total magnetic field, the MAGNETIC ANOMAL of a submarine is a very small fra ion o the total field present. However, it is infinitesimal "abnormality" or ANOMALY in earth's magnetic field, caused by the dip moment of the submarine, which magnetic anomaly detection equipment must detect.

The term that describes the distortion of earth's magnetic field caused by a submar dipole moment is called _____

_____.

magnetic anomaly

43. A MAGNETIC ANOMALY is the result of the magnetic field of the earth being _____ by petroleum or ore deposits or by the di moments of ships or _____

(1) _____ and

(2) _____.

45. What are the three magnetic moments of a submarine?

(1) _____

(2) _____

(3) _____

46. The term which describes the distortion of the earth's magnetic field caused by a submarine's dipole moment is _____ _____.

47. What two types of magnetism comprise each of the three magnetic moments of a submarine?

(1) _____

(2) _____

48. What term describes the distortion of the earth's magnetic field which is caused by a submarine's dipole moment?

_____

REVIEW TEST

1. What are two reasons why the earth may be compared to a bar magnet?

   (1) _____

   _____

   (2) _____

   _____

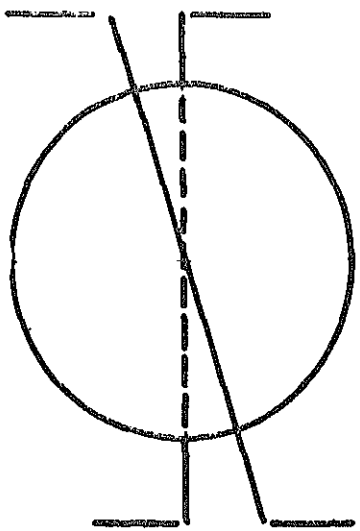
2. To which of the magnetic poles of the earth (N or S) does the north polarized end of a compass needle point? Explain your answer.

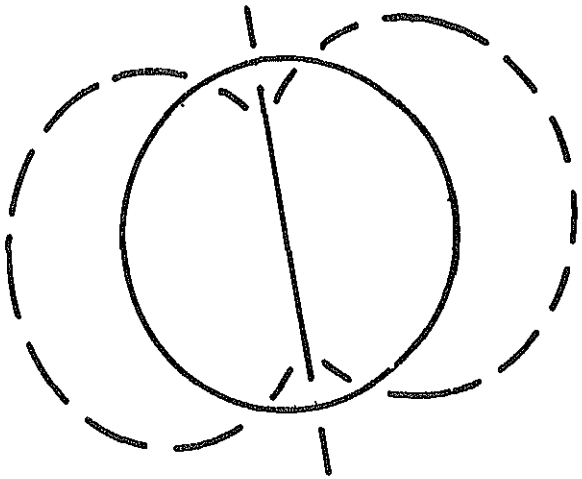
   _____

   _____

   _____

3. Label, on the drawing provided, the north and south magnetic and geographic poles of the earth.





5. What are the approximate angles, in relation to the surface, of the earth's external lines of force at the poles and at the equator?

   a. Poles: _____

   b. Equator: _____

6. What is the term which indicates the relationship of the angle between the earth's magnetic lines of force and its surface?

   _____

7. What is the commonest unit of measurement used to measure the intensity or strength of the earth's magnetic field?

   _____

8. What is the intensity of the earth's magnetic field at the equator and at the magnetic poles?

   a. Equator: _____

   b. Magnetic poles: _____

ıre the three magnetic moments of a submarine?

two types of magnetism comprise each of the three magnetic
ts of a submarine?

term describes the distortion of the earth's magnetic field
is caused by a submarine's dipole moment?